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September 21, 2009

Ex Parte

Julius Genachowski, Chairman
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: A National Broadband Plan for our Future; GN Docket Nos. 09-51, 09-137

Dear Chairman Genachowski:

Microsoft takes this opportunity to supplement our Comments and Reply Comments filed in the above-captioned proceedings. In particular, we take this opportunity to further explain why the Commission should adopt robust, future-proof broadband definitions and implement meaningful spectrum reforms. Such reforms will aid service providers' efforts to deliver richer broadband experiences to a wider array of consumers and will put the country on a path to be a global leader in broadband capability. In this letter, we:

1. Further highlight the urgency of the Commission's goal "for every American citizen and every American business to have access to robust broadband services."¹
2. Describe developments in telepresence and 3D capabilities and how those and many other developments will require consumers to have access to higher bandwidth connections.
3. Provide further support for our proposed broadband definitions, specifically our proposal to differentiate wireless broadband.

¹ See *A National Broadband Plan for Our Future*, GN Docket No. 09-51, Report and Order, FCC 09-31, at para. 1 (rel. Apr. 8, 2009).

4. Bolster the case for *both* licensed and unlicensed spectrum allocations and policies that promote efficiency-enhancing breakthroughs, such as software-defined radios and adaptive operations. In particular, we describe some of the economic benefits that can be derived from unlicensed spectrum allocations.
5. Summarize a recently-concluded economic study estimating that Wi-Fi broadband access in homes, Wi-Fi delivering voice services and wireless access to patient records in hospitals, and RFID tracking inventory in clothing retail stores together could generate as much as \$37 billion per year in economic value for the U.S. economy over the next 15 years. That analysis accounts for only about 15% of the total projected market for unlicensed chipsets. The paper is attached for your reference.

Broadband is Foundational to Our Economic Growth. Today's reality is that we can no longer sustain economic growth by simply relying on consumption or the easy availability of inexpensive debt. We must return to growth that has traditionally been built on innovation and productivity. Broadband is foundational for driving innovation and productivity across all market sectors including education, healthcare, and energy.

Core to driving innovation is better education and an increasingly skilled workforce. Microsoft believes that software and services can be a powerful catalyst for significant transformations in the way we learn. We believe that it can enable: Teachers and students to share in richer, more motivating and productive learning, wherever and whenever it suits them. What we are seeing today in leading edge educational settings is broadband and e-learning being used in combination with face-to-face teaching. An encouraging and important development in education is the increasing use of Virtual Schools and Virtual Classes. Approximately 30 states now have Virtual Schools with the biggest being the Florida Virtual School that serves about 100,000 students. Other Virtual Schools are substantially smaller, but are growing quickly.

Like many other companies, Microsoft sees the potential of broadband to deliver on innovation and achieve greater productivity gains. For example, here at Microsoft, we envision a connected health ecosystem that enables predictive, preventive, and personalized care. Telehealth technologies can be used to "remotely monitor patients, facilitate collaboration between medical professionals, exchange medical data and images, and instantaneously provide efficient emergency service to remote areas." We also see medical research increasingly manipulating the HUGE amounts of patient and genomics data for drug discovery and personalized medicine.

Logistics is an example of an area in which broadband can be leveraged to realize productivity gains. Today, the transport of global goods is growing rapidly, as a result of globalization and global economic growth. One of the things that we will see in

the future is that every object shipped, vehicle, loader, container, warehouse, etc, will be connected and the path of goods through the logistics chain will be optimized to drive greater efficiencies and productivity. In this world of interconnected devices, achieving "smart logistics" involves a range of software and hardware tools that monitor, optimize and manage operations, which helps reduce the storage needed for inventory, fuel consumption, kilometers driven and frequency of vehicles travelling empty or partially loaded.

Robust Broadband Infrastructure is Needed. There is little disagreement that consumers' increasing demand for bandwidth intensive applications is creating unprecedented challenges and opportunities for consumers, network operators, content providers, and technology companies. Technology trends continue to drive the need for increased bandwidth. Storage capabilities driven by Moore's law are doubling every 18 months. Applications quickly use this increased storage to deliver new value to consumers. So, for example, we see current generation Blue Ray discs capable of holding 50 GB of content² and MRIs at 3.6 GB.³ But, this is only today's standard and over time the amount of data utilized and stored will likely continue increasing in that 18 month doubling period. The increase in data traversing the network is also reflected in the reality that online content providers are making significant investments in building data centers to make available the online content consumers are demanding.

Intensifying the need for greater bandwidth is the fact that cloud computing is on the rise and as a result an increasing amount of content is traversing the Internet as personal computers, wireless handsets, and other devices seek to pull content from the cloud. For example, Facebook has reported that it has over 1.5 petabytes of users' photos stored, translating into roughly 10 billion photos.⁴ The four experiments in the Large Hadron Collider (LHC) will produce about 15 petabytes of data per year, which will be distributed over the LHC Computing Grid.⁵ As more and more technologies are introduced that rely on the cloud computing environment, consumers, including both small and large businesses, will be increasingly dependent on the robustness of broadband connectivity.⁶

Unfortunately, average throughput speeds for broadband connections are not keeping pace with storage capabilities or consumers' bandwidth needs. The amount of bandwidth available in a home is doubling at a substantially slower pace than the 18

² http://en.wikipedia.org/wiki/Blu-ray_Disc; <http://www.diskdatarecovery.net/blue-ray> (visited September 14, 2009).

³ http://hmi.ucsd.edu/pdf/HMI_Case_Neuroimaging.pdf (visited September 14, 2009).

⁴ http://www.facebook.com/note.php?note_id=76191543919&ref=mf (visited September 14, 2009).

⁵ <http://www.interactions.org/cms/?pid=1027032> (visited September 14, 2009).

⁶ A recent report from ABI Research predicts that over the next five years there will be almost a billion subscribers to mobile cloud services, up from only 42.8 million today. See David Needle, *Will Cloud Apps Hit 1B Subscribers?*, Internet News, September 8, 2009, available at <http://www.internetnews.com/mobility/article.php/3837921/Will%20Mobile%20Cloud%20Apps%20Hit%201B%20Subscribers.htm> (visited September 14, 2009).

month doubling period for storage. This discrepancy is already creating a bandwidth bottleneck and the situation will get worse not better over time due to the difference in the doubling periods. According to Werner Vogels, Amazon.com's Chief Technology Officer, "No matter how much we have improved our network throughput in the past 10 years, our datasets have grown faster, and this is likely to be a pattern that will only accelerate in the coming years."⁷

As described in greater detail below, the need for more bandwidth will only accelerate as technologies like telepresence and three dimensional (3D) imaging enable us to experience a world of educational, health-related, and other services that are much improved over what is available today from 2-D offerings. The future also entails devices working on our behalf, the so called "Internet of Things." This is a world in which devices in our everyday world are connected to each other. We see the beginnings of this today in object locator or remote meter reading technologies. As machines increasingly talk to other machines, the need to increase network capacity will again be raised since the level of machine-to-machine communication is not limited by human population.

Much of the machine-to-machine traffic will be done via wireless. For example, a wireless-enabled pacemaker has been developed that allows remote monitoring of the health of the patient.⁸ As time goes by we will see radios in just about every device. The speed at which this wireless revolution is occurring is highlighted by a report from ABI Research, which projects that Wi-Fi chipset vendors will ship 1 billion units by 2011. By the end of the following year, a cumulative 5 billion such chipsets will have shipped since the firm began tracking Wi-Fi chipsets in 2000.⁹

3D and Telepresence Innovations. Some of the key innovations that will likely drive increases in higher bandwidth broadband demand include those emerging from 3D and telepresence research. Microsoft and many others are actively developing consumer, health, education, and business applications with 3D imaging and telepresence capabilities.¹⁰ Some believe that these immersive experiences enabled by

⁷ See http://www.allthingsdistributed.com/2009/05/amazon_import_export.html (visited September 14, 2009).

⁸ See http://www.sjmprofessional.com/Products/US/Pacing-Systems/~media/SJM%20Products/Documents/Spec%20Sheets/Accent_Pacemaker_SR_RF_1210_SpecSheet_US.ashx (visited September 14, 2009).

⁹ See Andrew Berg, *Projection: 1 Billion Wi-Fi Chipsets Shipped in 2011*, Wireless Week, August 18, 2009, available at <http://www.wirelessweek.com/News-Projection-1Billion-Wi-Fi-Chipsets-2011-081809.aspx> (visited September 13, 2009).

¹⁰ Research includes: (a) the World's first 3D webcam - Minoru. <http://www.minoru3d.com/>, (b) changes in entertainment and games, e.g., Xbox, Project Natal <http://www.xbox.com/en-US/live/projectnatal/>, (c) efforts underway in Europe on 3D TV over the Internet, (d) the NSF funded TEEVE project jointly studied by UIUC and UC Berkeley <http://cairo.cs.uiuc.edu/projects/teleimmersion/index.html>, (e) Camera and projector arrays, e.g., the work from HP labs http://www.hpl.hp.com/personal/Harlyn_Baker/papers/ImmerscomII-Baker-Li-3D-ACM.pdf, and (f) Work

3D imaging and telepresence technologies will lie at the core of the next generation of computing applications: highly efficient human-to-human communication mediated by the computer.

Innovation in information technology comes in *waves* of new *technologies* and *experiences*. As the following graphic illustrates, waves of new *technologies* build up and crest.



Waves of new *experiences* – killer applications – are triggered by the waves of new technologies. For example, Word Processing depended, for its broad availability, on the development of the PC and DOS. Spreadsheets depended on the development of graphic user interfaces (GUIs) and Windows. Email and Web Browsing depended on the development of SMTP, HTTP, and HTML. Internet Search depended on the development of crawling, indexing, and global scale data centers. These waves of technology and experiences have given rise to the DOS era, the GUI era, the Internet era, and the present Client+Cloud era.

Today there are numerous technologies rising to a crest such as distributed services, multicore processing, broadband networks, large high definition displays, sensor networks, natural user interfaces (NUI), and so forth. Telepresence, taken

on multi-view compression by Dinei and Chou

<http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4959669&isnumber=4959496?tag=1> (visited September 14, 2009). See also IEEE Signal Processing Magazine, Special issue on multiview imaging and 3DTV, Vol. 24, No. 6, Nov. 2007.

<http://ieeexplore.ieee.org/xpl/tocresult.jsp?isYear=2007&isnumber=4387664&Submit32=View+Contents> (visited September 14, 2009).

broadly to be rich and efficient human-to-human communication mediated by computer, integrates and relies on these emerging technologies and is positioned to meet user needs arising from a confluence of current social and economic factors.

Several critical factors make efficient telepresence solutions increasingly attractive to consumers. First, with the global downturn in the economy, increased productivity that is “doing more with less” has become an economic imperative. These types of resource constraints may be particularly acute for small businesses, which account for 98% of all businesses with employees, 27% of business receipts, and 36% of jobs in the United States.¹¹ The small business sector is responsible for over 40 million jobs and over \$6 trillion in revenues.¹² Despite huge improvements in business productivity afforded by computers, today, American small business use of the Internet is typically limited to a simple web page and some minor marketing.¹³ Most information work continues to rely heavily on interactions between people. Thus, there is an increasing need for efficient interpersonal work processes. Telepresence may be a step in that direction. In the past several years, Microsoft has noticed an uptick in the use of our remote meeting products and services, such as Live Meeting and Sharepoint.

Second, with the threats of global climate change and economic and political instability due to oil consumption, energy conservation has become a global imperative. Physically transporting people is not only time-consuming; it is highly energy-consuming. In comparison, the energy to transport a person’s “presence” electronically is negligible. Telepresence can conserve energy and its concomitant social costs, in scenarios from off-site business meetings to telecommuting.

Third, with increasing globalization and “flattening” of our world, not only has it been increasingly possible, but it has also been increasingly *necessary* for employers to recruit employees to work wherever they may live around the world. Likewise it has been increasingly necessary for workers, wherever they may live, to find employment with companies, wherever they may be, and similarly for businesses to find their clients. In fact, there is a significant movement towards fully distributed virtual companies. Telepresence can be exploited to play a pivotal role in this global trend.

Fourth, physical security is increasingly a concern, whether the threats are from political instability or from pandemics. Telepresence can help remove these concerns and keep the economy moving.

¹¹ http://growsmartbusiness.com/wp-content/files/ABRIDGED_State_of_Small_Business_Report_3-12-09.pdf (visited September 14, 2009). 2009 Baseline Study of Small Business Success, Network Solutions, LLC and the Robert H. Smith School of Business, University of Maryland, with Rockbridge Associates, Inc.

¹² U.S. Census Bureau, including: 2002 Economic Census, 2006 Statistics of U.S. businesses, 2006 Nonemployer Statistics. Business receipts and revenues are based on businesses with payrolls.

¹³ U.S. Small Business Internet 2007–2011 Forecast, IDC Study 206039, Raymond Boggs. IDC defined small business as businesses with 100 or fewer employees and not including home-based businesses.

Across the trend of increasing consumer need are the industry trends of decreasing costs of computation and image resolution.

- *Computation* continues to get exponentially cheaper as Moore's Law – the doubling of transistor density every 18-24 months – continues unabated. For computation, Moore's Law is now being expressed as increasing numbers of cores on a chip, rather than increasing clock frequency. However, this meshes well with the needs of Telepresence, which is highly parallelizable and scalable in network bandwidth and display resolution.
- *Image resolution*: Pixels in both cameras and displays also appear to be getting exponentially cheaper with Moore's Law. Only a few years ago, 2.3 megapixel digital cameras and camera phones were the norm. Now 8+ megapixels are common consumer fare, with 20+ megapixel cameras available. Demand for notebook computers, flat screen televisions, and large-screen projectors has driven down the unit cost of large displays, while demand for mobile phones has driven down the unit cost for smaller displays.

These trends in part are driving the need for greater communications bandwidth.

- *Communication bandwidth* needs are rapidly increasing. The research of Tekalp and Wu suggest that standard definition 3D video streams will require downstream throughput of 30 Mbps.¹⁴ They reason that as 3D becomes more pervasive, these demands on the network would expand significantly.¹⁵ Another challenge that researchers are working to mitigate is latency, since low latency is critical for interactive communication.¹⁶ In their

¹⁴ In the special issue just mentioned, the paper, "3DTV over IP" by Tekalp et al., gives the following bandwidth figures for standard definition video: "[E]ven with the state-of-the-art compression, bit rates for multiview video (MVV) are still high: 38 dB peak signal noise ratio (PSNR) at about 5 Mb/s is a common operating point for 704 × 480, 30 f/s, 8-view video using MVC." For high definition (1920 × 1080) the figure would be over 30 Mbps. Similarly, Wu et al. conclude that "The data rate per 3D stream can be large (e.g., $r = 30$ Mbps)." Whitepaper submitted to IEEE Signal Processing Magazine special issue on Immersive Communication, Wanmin Wu, Zhenyu Yang, and Klara Nahrstedt (UIUC CS Dept.) This whitepaper is currently under review. See also Special Issue on Multiview Video Coding in the IEEE Transactions on Circuits and Systems for Video Technology, Nov. 2007

(<http://ieeexplore.ieee.org/xpl/tocresult.jsp?isYear=2007&isnumber=4373313&Submit32=View+Contents>) (including surveys on scene capture technologies, scene representation technologies, coding algorithms, transport methods, and display technologies) (visited September 14, 2009).

¹⁵ Each environment usually consists of many 3D cameras (e.g., $N_s = 50$) that capture data from different angles. Multiple sites can be participating in one session (e.g., $N_g = 10$). In each environment, many displays can be deployed to present the data panoramically (e.g., $N_d = 5$). Thus the maximal bandwidth requirement can be as large as $r \times N_s \times N_g \times N_d$ for each source site. For a multi-party session, the amount of traffic across the network will be enormous." *Id.*

¹⁶ See Dave Patterson's article, "Latency Lags Bandwidth," <http://delivery.acm.org/10.1145/1030000/1022596/p71-patterson.pdf?key1=1022596&key2=2183599421&coll=GUIDE&dl=GUIDE&CFID=47016133&CFTOKEN=27>

comments on the broadband definition, the Fiber-to-the-Home Council notes that robust throughput can help address concerns about latency.¹⁷

The relationship between local computation relative to local bandwidth *and* screen real-estate is consequently going through an order of magnitude change which is going to fundamentally affect architectures, services and the nature of usage. In addition, these technological innovations are converging with the economic and social predicates outlined above. Taken together it seems clear that the nature of applications and services will change, perhaps as dramatically as they did 20 years ago when PCs with minimal memory networked together to form the Internet. And with these innovations, bandwidth needs will only increase.

Baseline Broadband Definition for Wireless Connections. The benefits of technology diversity should be recognized in how the Commission defines broadband. In its recent Notice of Inquiry on developing a National Broadband Plan, the Commission asked whether it should adopt different definitions of broadband for different technology platforms. In particular, the FCC asked “should a different set of standards be used to identify mobile broadband services – which allow mobility or portability but may have lower throughputs – and fixed broadband services?”¹⁸ While Microsoft generally opposes technology-specific broadband definitions (which risk discouraging innovation), we have suggested that the FCC adopt a modified, but evolving definition of baseline broadband for wireless services to reflect the physical limits of spectrum based services. As supported in greater detail below, we propose the following baseline broadband definition for wireless: at least 1.5 Mbps downstream and at least 700 kbps upstream. As discussed below, this level of performance is achievable using the latest iterations of 3G mobile wireless broadband technology. As others have proposed, throughput should be measured at peak traffic periods using statistically significant methods (not based on theoretical speeds rarely ever achieved),¹⁹ which will ensure that consumers can utilize applications that are now so essential. The chart below

[236233](#) (visited September 14, 2009). See also a paper under review by Jeremy Copperstock (McGill) (“Latency is a fundamental issue in computer-mediated human communications, in particular for applications such as music for which the timing is critical. Significant advances have been achieved in supporting networked musical practice by reducing encoding and decoding latency.”); citing C. Chafe, M. Gurevich, G. Leslie, and S. Tyan. Effect of time delay on ensemble accuracy. In Proceedings of the International Symposium on Musical Acoustics, 2004; A. Dix. Network-based interaction. In A. Sears and J. A. Jacko, editors, Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies, and Emerging Applications. L. Erlbaum Associates Inc., Hillsdale, NJ, USA, 2002.

¹⁷ See FTTH Council Comments in GN Docket Nos. 09-47, 09-51, 09-137, at 6 (filed Aug. 31, 2009).

¹⁸ See *In the Matter of A National Broadband Plan for Our Future*, GN Docket No. 09-51, FCC 09-31 at para. 19 (rel. Apr. 8, 2009).

¹⁹ See Comments of Free Press – NBP Public Notice #1 (filed Aug. 31, 2009); Comments of Fiber-to-the-Home Council (filed Aug. 31, 2009).

summarizes our proposed definitions of broadband.²⁰

Category	Minimum Downstream Speed	Minimum Upstream Speed
Baseline Broadband for Households	4 Mbps	1 Mbps
Wireless Broadband	1.5 Mbps	700 kbps
Anchor Institutions	100 Mbps	100 Mbps

These broadband definitions should scale upward as more capabilities come online and become widely available across the country. In the case of wireless, the broadband definition should scale upward as 4G networks are deployed more broadly. As we have noted before, others have proposed higher thresholds and we would be supportive of higher minimum thresholds to the extent the FCC chooses to establish them.²¹

Wireless and wireline technologies deliver different capabilities with their own positive and negative attributes, and those capabilities have different degrees of upward scalability. Mobile wireless broadband provides the benefit of mobility or portability, delivering “broadband to the person.”²² This benefit is increasingly valued by consumers. According to the FCC, since 2005, mobile wireless broadband has been the fastest growing customer segment.²³ That growth is primarily limited to the FCC’s lowest tier of high-speed lines (*i.e.*, those exceeding 200 kbps in only one direction).²⁴ Data from the Pew Internet & American Life Project reveal that as of April 2009, 56% of adult Americans have accessed the Internet by wireless means.²⁵ The most prevalent way people get online using a wireless network is with a laptop computer; 39% of adults have done this.²⁶ One-third of Americans (32%) have used a cell phone or smartphone to access the internet for emailing, instant-messaging, or information-seeking.²⁷ On the typical day, nearly one-fifth of Americans access the Internet using a mobile device.²⁸ The Pew study reports that consumers particularly value their mobile broadband connectivity when away from home or the office.²⁹

²⁰ See Microsoft Reply Comments (filed Jul. 21, 2009). We also proposed that the baseline broadband definition for households include a minimum monthly data-consumption allowance. See *id.* at 2-3.

²¹ See Microsoft Reply Comments at 4-5 (filed Jul. 21, 2009).

²² See CTIA Reply Comments at 3-4 (filed Jul. 21, 2009).

²³ See Report of the Wireline Competition Bureau, Industry Analysis and Technology Division, *High-Speed Service for Internet Access: Status as of December 31, 2007* (rel. Jan. 2009).

²⁴ See *id.* at Table 5.

²⁵ See John Horrigan, Associated Director, Pew Internet & American Life Project, Data Memo, Wireless Internet Use (July 2009), available at <http://www.pewinternet.org/Reports/2009/12-Wireless-Internet-Use.aspx> (visited September 14, 2009).

²⁶ *Id.*

²⁷ *Id.*

²⁸ *Id.*

²⁹ *Id.* at 5.

In addition, mobile wireless broadband is often less costly to deploy on average than wireline broadband (especially in rural areas), since wireless broadband can be provided to many users in a given area from a single tower, whereas wireline broadband relies on “last-mile” facilities built out to each end user’s fixed location.³⁰ The Consumer Federation of America has estimated that wireless is less than one tenth as expensive to deploy as fiber.³¹

On the other hand, mobile broadband speeds are simply lower than those achievable using fixed wireline broadband connections. Fiber-based wireline broadband connectivity can deliver symmetrical throughput of 100 Mbps or more and is sold without any monthly caps on data consumption. Fourth Generation (4G) mobile wireless broadband technologies, such as Long Term Evolution,³² can in theory deliver throughput speeds of 173 Mbps downstream and 58 Mbps upstream.³³ But, the actual or average throughput speeds for wireless broadband services are *significantly* lower than theoretical throughput speeds. Shannon's law -- that channel capacity is for a finite bandwidth -- combines with limited spectrum availability to make the bandwidth of wireless more limited when compared to fiber-based approaches.³⁴

Spectrum places a hard limit on capacity, which must be rationed in order to deliver a consistent customer experience. Moreover, mobile broadband speeds vary due to weather, foliage, physical location, variable system loading, backhaul capacity, distance from the mobile base station, and other factors.³⁵ Rysavy Research estimates typical user rates of 10 Mbps downstream and 5 Mbps upstream for LTE.³⁶ According to Verizon Wireless Chief Technology Officer Terry Melone, the results of initial trials indicate that LTE will supply average download speeds of 7 to 12 Mbps.³⁷

³⁰ See, e.g., Sprint Comments at 5 (filed June 8, 2009).

³¹ See Comments of Consumer Federation of America and Consumers Union, at 22 (filed Jun. 9, 2009).

³² Verizon has announced plans to begin deploying LTE in the U.S. in 2010. See Karl Bode, *Verizon to Test LTE in Seattle and Boston*, DSL Reports, Jul. 28, 2009, available at <http://www.dslreports.com/shownews/Verizon-To-Test-LTE-In-Seattle-And-Boston-103650> (visited Sep. 13, 2009).

³³ See EDGE, HSPA and LTE BROADBAND INNOVATION, Rysavy Research, September 2008, at 37-39, available at http://www.rysavy.com/Articles/2008_09_Broadband_Innovation.pdf (visited Sep. 13, 2009) (*Rysavy Research Report*).

³⁴ See, e.g., Kevin Fitchard, *Shannon's Specter*, Telephony Online, May 21, 2007, available at http://telephonyonline.com/mag/telecom_shannons_specter/ (visited Sep. 13, 2009).

³⁵ These factors explain consumers’ continued concerns about signal or reception problems. According to Ofcom, “issues with signal and reception are a primary factor of consumer concern – as significant in importance as the cost of services, in unprompted feedback.” See *Mostly Mobile: Ofcom’s mobile sector assessment*, Second Consultation, at 117-118, available at <http://www.ofcom.org.uk/consult/condocs/msa/msa.pdf> (Jul. 8, 2009).

³⁶ Rysavy Research Report at 39.

³⁷ See Phil Golstein, *Can you hear my LTE call now? Verizon begins 4G rollout*, FierceWireless, August 14, 2009, available at <http://www.fiercewireless.com/story/verizon-begins-lte-trials/2009-08-14> (visited Sep. 3, 2009).

Throughput speeds for the latest Third Generation (3G) mobile wireless broadband services are slower yet. For example, High Speed Packet Access (HSPA) technology being utilized by AT&T in the United States can in theory deliver throughput speeds of up to 7.2 Mbps downstream and 5.76 Mbps upstream, but typically deliver 700 kbps to 1.7 mbps downstream and 500 kbps to 1.2 Mbps upstream.³⁸ Evolution Data Optimized (EV-DO) Rev A technology being deployed by Verizon and Sprint in the United States can in theory deliver throughput speeds of 3.1 Mbps downstream and 1.8 Mbps upstream, but typically deliver 600 kbps to 1.4 Mbps downstream and 300 to 500 kbps upstream.³⁹ While these levels of throughput enable a customer on the go to send and receive e-mail, surf the Web, and view limited amounts of video, they limit a customer's ability to experience the full benefits of today's (and tomorrow's) video, gaming, and advanced data applications.

Moreover, unlike fiber-based broadband providers, wireless network operators often utilize monthly data-consumption allowances as a tool to manage the large amount of traffic traversing their network. Given the anticipated increase in traffic over the network, if substantial additional capacity isn't made available wireless carriers will continue utilizing pricing structures, such as monthly data-consumption allowances and metered pricing that discourages heavy network use.⁴⁰

In summary, wireless and wireline broadband connectivity remain complementary from a consumer and network deployment perspective, with their own positive and negative attributes. Any definition of broadband should account for these differences, but should be increased periodically.

Unlicensed Spectrum Evaluation. Spectrum reform should be a centerpiece of any National Broadband Plan. Spectrum reform should include an assessment of whether existing spectrum allocations are being fully utilized and stepping up efforts to increase both licensed and unlicensed access to underutilized spectrum. Significant amounts of valuable spectrum below 3 GHz remain underutilized – in particular, spectrum held by the federal government. In order to meet the increasing wireless needs of consumers, more licensed and unlicensed spectrum must be made available. Nonetheless, to address a gap in the economic literature, the discussion below focuses on the economic and consumer benefits of unlicensed applications. In parallel to new spectrum allocations, the Commission should continue to encourage efficiency-enhancing breakthroughs, such as software-defined radios and adaptive operations like those approved in the Commission's white spaces decision.

³⁸ Rysavy Research Report at 37-39.

³⁹ *Id.*

⁴⁰ See generally <http://www.wireless.att.com/cell-phone-service/legal/plan-terms.jsp#msg> (AT&T DataConnect Plans); http://nextelonline.nextel.com/en/legal/legal_terms_privacy_popup.shtml (Sprint data usage limitation); <http://www.verizonwireless.com/b2c/mobilebroadband/?page=plans> (Verizon Wireless data plans) (all sites visited Sep. 13, 2009).

In the attached paper by Richard Thanki, *The Economic Value Generated by Current and Future Allocations of Unlicensed Spectrum*, technologies utilizing unlicensed spectrum are delivering significant innovation and economic value.⁴¹ Unlicensed uses provide a number of benefits including: (1) Unlicensed networks being deployed rapidly by individual users (or groups of users) when and where needed; (2) Decentralized unlicensed network deployments can prove more resilient, for example, in the aftermath of natural disasters; (3) Allowing network access in offices, factories and homes without having to lay cable can improve consumer and business efficiency; (4) Unlicensed white space offers a way to extend the coverage of 2.4 GHz Wi-Fi hotspots; (5) Because unlicensed uses can occur without the permission of licensed network operators, they provide more opportunities for innovation; and (6) Technological and business innovations first developed in the unlicensed context have translated to broad consumer benefits in both licensed and unlicensed contexts.

Indeed, many innovations often credited to licensed wireless uses occurred first in unlicensed environments. For example, orthogonal frequency division multiplexing (OFDM) is a modulation technique first standardized for use in the wireless local area networks (LANs) in 1999. Seven years later, in 2006, OFDM first appeared in the Long Term Evolution (LTE) standard, now primarily being used for licensed 4G mobile wireless broadband networks. For many of the reasons discussed above, Thanki suggests that “unlicensed spectrum may have a greater potential for innovation than licensed spectrum.”⁴²

Wi-Fi provides a powerful example of innovation occurring first in the unlicensed space and then adapted for use in a traditionally licensed context. Although U.S. wireless carriers initially resisted including Wi-Fi antennas in smartphones, according to CTIA-The Wireless Association, there are now at least 29 devices for sale in the U.S. with integrated Wi-Fi capabilities.⁴³ An indication of how much U.S. wireless carriers have come to embrace unlicensed applications is reflected in the following statement from Christopher Guttman-McCabe, CTIA’s Vice President of Regulatory Affairs, “Hopefully, we will continue to see technology innovation in white spaces. . . We hope that the spectrum gets put to good use. And as we’ve seen with Wi-Fi, I’m sure that as the technology and services evolve, carriers will contemplate incorporating white space spectrum into their own services.”⁴⁴

To facilitate that unlicensed connectivity, all the major U.S. wireless carriers now enable their broadband subscribers to utilize networks of Wi-Fi hotspots, which

⁴¹ See Richard Thanki, *The Economic Value Generated by Current and Future Allocations of Unlicensed Spectrum* (Sep. 2009) (“Thanki Report”).

⁴² *Id.* at 43.

⁴³ See Comments of CTIA-The Wireless Association in WT Docket No. 09-66 at (filed July 13, 2009).

⁴⁴ See Marguerite Riorden, *Microsoft detail as fix for ‘white space’ interference*, CNET News, Aug. 19, 2009, available at http://news.cnet.com/8301-30686_3-10313710-266.html (visited August 20, 2009).

decrease capacity constraints on their Third Generation (3G) mobile wireless broadband networks,⁴⁵ to extend service availability, and to deliver higher bandwidth connectivity to consumers.⁴⁶ Recent speed tests conducted by Xtreme Labs, Inc. show that worldwide 3G average download speeds were clocked at 956 kbps versus upload speeds of 153 kbps and 484 milliseconds latency. In comparison, the average Wi-Fi network speeds were clocked at 2.502 Mbps download, 774 kbps upload and 205 milliseconds latency.⁴⁷ AT&T, for example, offers its consumers access to over 20,000 Wi-Fi hot spots in the U.S.⁴⁸ Sprint Nextel recently announced that it will feature Wi-Fi in all of its “major devices going forward.”⁴⁹ Verizon Wireless has made similar statements regarding smartphones.⁵⁰ Wireless carriers also are increasingly marketing personal “MiFi” mobile hot spots.⁵¹ According to AT&T, its “Wi-Fi network complements its wired broadband and wireless 3G networks with Wi-Fi hotspots including retail stores, restaurants and airports from coast-to-coast.”⁵² AT&T, for one, has seen explosive growth in unlicensed Wi-Fi broadband connectivity.⁵³

While Wi-Fi connectivity is often (inaccurately) styled as a “free” add-on to paid wireless and wireless broadband subscription, wireless carriers are pursuing other

⁴⁵ To further alleviate capacity constraints, the Commission also should continue promoting efficiency-enhancing breakthroughs, such as software-defined radios and adaptive operations.

⁴⁶ See, e.g., *Verizon Wireless fires up hot spots*, CNET News, August 5, 2009, available at http://news.cnet.com/Verizon-Wireless-fires-up-hot-spots/2100-1037_3-5060071.html (visited Aug. 5, 2009). The major cable providers also are extending their broadband footprints by offering their customers Wi-Fi hot spot access.

⁴⁷ See David Fraser, *Wi-Fi: The Better, Smarter, Faster Network*, Converge! Network Digest, August 5, 2009, available at <http://www.convergedigest.com/bp/bp1.asp?ID=598&ctgy=2> (visited Aug. 18, 2009).

⁴⁸ See AT&T *Wi-Fi Support Auto-Authentication on New iPhone OS 3.0 for Faster Hot Spot Connections*, Press Release, June 17, 2009, available at <http://www.att.com/gen/press-room?pid=4800&cdvn=news&newsarticleid=26865> (visited Aug. 5, 2009).

⁴⁹ See Sprint’s Blackberry Tour to sprout WiFi Next Year, *FierceWireless* available at <http://www.fiercewireless.com/story/sprints-blackberry-tour-sprout-wifi-next-year/2009-07-09> (visited Aug. 6, 2009).

⁵⁰ See Reinhardt Krause, *Verizon Confirms: It’s Embracing Wi-Fi*, *Investors Business Daily*, September 8, 2009, available at <http://www.investors.com/NewsAndAnalysis/Article.aspx?id=505523> (visited Sep. 9, 2009) (“The vast majority of PDAs and smart phones that we launch from this moment forward are going to be Wi-Fi-enabled”).

⁵¹ See, e.g., Verizon Wireless and Sprint MiFi offerings available at: <http://www.verizonwireless.com/b2c/store/controller?item=phoneFirst&action=viewPhoneDetail&selectedPhoneId=4726> ; <http://mobilebusiness.sprint.com/broadband/index.html?pid=5&id9=vanity:mifi> (visited August 6, 2009).

⁵² See AT&T *Wi-Fi Support Auto-Authentication on New iPhone OS 3.0 for Faster Hot Spot Connections*, Press Release, June 17, 2009, available at <http://www.att.com/gen/press-room?pid=4800&cdvn=news&newsarticleid=26865> (visited Aug. 5, 2009).

⁵³ In the second quarter, AT&T handled nearly 15 million Wi-Fi connections on its network — a 41 percent increase over the first quarter. With approximately 25.6 million connections so far in 2009, AT&T Wi-Fi connections this year have already surpassed the 20 million connections seen in all of 2008. See AT&T *Sees Significant Rise in Wi-Fi Hotspot Connections during Second Quarter*, Press Release, July 28, 2009, available at <http://www.att.com/gen/press-room?pid=4800&cdvn=news&newsarticleid=26975> (visited Aug. 5, 2009).

business models, including charging for daily and monthly Wi-Fi access.⁵⁴ Unlicensed Wi-Fi connectivity is of such value that competing wireless carriers are reportedly negotiating deals for roaming rights on each other's Wi-Fi hot spots, much as wireless carriers today negotiate for Commercial Mobile Radio Service (CMRS) network voice and data roaming rights.⁵⁵ The popularity of Wi-Fi continues to increase at a rapid pace. According to the Wi-Fi Alliance, global Wi-Fi chipset sales grew 26 percent to 387 million in 2008.⁵⁶

But, Wi-Fi is just one of many unlicensed applications in everyday use. As the chart below from Richard Thanki's paper illustrates, the unlicensed ecosystem is quite broad, encompassing a wide variety of platforms and devices, including commonly-used cordless phones, Wi-Fi routers, Bluetooth devices, and baby monitors, as well as specialty uses such as meter readers and telemetry.⁵⁷

	Consumer	Commercial	Educational	Healthcare	Industrial	Government
Wireless LANs 802.11/Wi-Fi	Broadband extension					
	Local area networks					
	Consumer electronics	Commercial hotspots	Campus networks	Records management	Process monitoring	Municipal networks
	Home monitoring	Card payments			Process control	Wide-area systems control
					Process automation	
Wireless PANs 802.15.1/Bluetooth	Personal area networks					
	Mobile phone headsets			Medical devices		
	Remote controls	Bluetooth marketing				
RFID	Contactless payment				Asset tracking	
	Transport payment	Supply chain		Human implants		
	Identification	In-store		Drug authenticity		
Low data rate wireless PANs 802.15.4/Zigbee	Smart metering					
	Sensor networks					
	Home control	Premises control		Exact process monitoring		
				Exact process control		
				Exact process automation		
Microwave/WiMAX	Mobile and fixed broadband					
	Point-to-point connections					
WirelessHD, WiGig	Wireless HD displays					
	Very high rate data transfer					
					Existing uses	
					Uses in development	

Explosive growth of licensed wireless applications is often cited as justification for greater access to licensed spectrum, but unlicensed applications show even greater

⁵⁴ According to a recent report, Verizon "is charging \$7 to use the service for 24 hours. Unlimited monthly access costs \$35." See *supra* article referenced at note 46. See also AT&T's Wi-Fi offerings at <http://www.att.com/gen/general?pid=5949> (visited Aug. 6, 2009).

⁵⁵ See Ben Charny, *Hot-spot deal adds fuel to the Wi-Fi debate*, CNET News, July 21, 2009, available at http://news.cnet.com/Hot-spot-deal-adds-fuel-to-Wi-Fi-debate/2100-1039_3-5050738.html?tag=mncol (visited Aug. 5, 2009).

⁵⁶ See http://www.wi-fi.org/pressroom_overview.php?newsid=770 (visited Sep. 13, 2009).

⁵⁷ See *Thanki Report* at 16.

growth potential. According to Mr. Thanki, through 2014, “[t]he shipments of hybrid devices, including Wi-Fi and Bluetooth-enabled mobile phones, 3G and 4G enabled laptops, Wi-Fi enabled televisions and set-top boxes, and cars possessing Bluetooth will likely double The sales of devices using only unlicensed spectrum are likely to soar, led by Wi-Fi and Bluetooth enabled consumer electronics and laptops, 802.15.4 devices in the consumer, commercial and industrial sectors, and RFID devices.”⁵⁸ These trends demonstrate the significant and growing value consumers are placing on devices and applications utilizing unlicensed connectivity.

Although always an imprecise exercise, much has been written on the economic value of licensed spectrum allocations. In the licensed context, economists often rely on factors such as auction results from different spectrum allocations and the impact of prices on demand to make inferences about producer and consumer surplus. These data points do not exist for unlicensed spectrum. That the economic benefits of unlicensed spectrum allocations are hard to quantify does not mean that the benefits are not massive.

In the attached paper, Richard Thanki estimates the U.S. economic value generated by the following unlicensed applications: (1) Wi-Fi broadband access within homes, (2) voice over Wireless local area networks and wireless electronic health records in hospitals, and (3) RFID tags for in-store item-level tagging in the clothing retail sector. Accounting for only about 15% of the total projected market for unlicensed chipsets, Thanki estimates that the annual consumer surplus generated by Wi-Fi in the United States in homes is between \$4.3 and \$12.6 billion.⁵⁹ That translates to a consumer surplus per U.S. household per month of between \$5.40 and \$15.70. By increasing the value of broadband connections, Wi-Fi may be driving home U.S. broadband adoption by anywhere between 4.3 to 9.8 million additional connected households.⁶⁰ It is important to stress that these estimates do not account for wireless carriers’ and consumers’ increased use of unlicensed Wi-Fi as a complement to licensed 3G mobile wireless broadband connectivity. They also do not account for the considerable economic benefits associated with business, educational, and other uses associated with Wi-Fi connectivity.

The economic benefits are equally compelling for wireless local area networks in U.S. hospitals. According to Thanki, the projected cost savings generated by use of voice over Wi-Fi and wireless electronic health records in U.S. hospitals come to a net present value of \$92 to \$154 billion, or an annualized \$9.7 to \$16.3 billion a year between 2009 and 2025.⁶¹ These cost savings can translate to reduced costs and/or resources reallocated to improving the quality of healthcare for patients. Likewise, Thanki

⁵⁸ See *id.* at 19.

⁵⁹ See *id.* at 27.

⁶⁰ *Id.*

⁶¹ See *id.* at 30.

estimates the annual economic value derived from using RFID tags for in-store item-level tagging in the U.S. clothing retail sector of \$2.0 to \$8.1 billion per year between 2009 and 2025.⁶²

The chart below summarizes the annualized economic benefits from Thanki's analysis of selected unlicensed applications:

Summary of modelled economic benefits of selected unlicensed applications in the US

Scenarios (2009 – 2025)	Low	Medium	High
Economic value generated by home Wi-Fi (\$ billions)	4.3	8.4	12.6
Economic value generated by hospital Wi-Fi (\$ billions per year)	9.6	12.9	16.1
Economic value generated by clothing RFID (\$ billions per year)	2.0	4.1	8.1
SUM OF ANNUAL ECONOMIC VALUE (\$ billions per year)	16.0	25.4	36.8

The three applications Thanki chose to analyze – Wi-Fi enhancing broadband access in homes, Wi-Fi delivering voice services and wireless access to patient records in hospitals and RFID tracking inventory in clothing retail stores – together may generate \$16 to \$37 billion per year in economic value for the U.S. economy over the next 15 years.

What is perhaps most compelling about this analysis is what it does not included. This analysis also does not include unlicensed uses such as Bluetooth, RFID beyond the U.S. clothing retail sector, cordless phones, telemetry, monitoring, sensor networks, and other applications. In light of widespread adoption, it would not be unreasonable to assume that these technologies deliver economic value of a similar magnitude to household Wi-Fi, wireless local area networks in hospitals, or RFID in the clothing retail sector. This analysis also does not account for the incredible consumer potential that in the United States can now be derived from unlicensed white spaces below 1 GHz (with better propagation characteristics). Indeed, Richard Thanki submits that the historical lack of unlicensed spectrum allocations below 1 GHz has “retarded the development of longer-range, more reliable and ultra lower-power unlicensed applications.”⁶³

Mesh networking is a case in point. Microsoft has conducted extensive research since 2003 that demonstrates that mesh networking in the 2.4 GHz spectrum band using Wi-Fi nodes is viable in suburban settings. Specifically, our study shows that for a typical suburban topology, such as the one in Sammamish, Washington, only 5 to 10% of the households in the community would need to participate in order to create a viable mesh network. We define a viable mesh network as a mesh network that contains at least 25

⁶² See *id.* at 34.

⁶³ See *Thanki Report* at 42-43.

participating nodes with each node having at least 2 points of connection to the Internet. Each participating node has a range equal to the range of a current 2.4 GHz Wi-Fi device. The requirement that each node has at least 2 points of connection to the Internet ensures that the network is resilient to random link failures. The capacity of the mesh nodes is related to the number of mesh egress points to the Internet.

The use of white spaces spectrum below 1 GHz would significantly improve the economics of that deployment. Key differentiators between 2.4 GHz spectrum and spectrum below 1 GHz are range and in-building penetration. At 2.4 GHz, Wi-Fi ranges are typically between 100 to 250 meters outdoors. In comparison, the range of white space devices is about three to five times greater using the same technical parameters but utilizing spectrum below 1 GHz.⁶⁴ A three times increase in range translates to an increase in the area of coverage by a factor of nine. Superior penetration is the other important difference between 2.4 GHz and white spaces spectrum below 1 GHz. One of the problems with Wi-Fi based meshes was that some subscribers sitting indoors could not connect due to poor propagation properties. UHF radio waves propagate better so outdoor meshes using white spaces spectrum (for scenarios like blanket area-wide coverage) will be able to provide connectivity for subscribers sitting indoors.

In comments filed in response to the FCC's National Broadband Plan NOI, a wide cross-section of parties agreed that, while some spectrum is being intensively used, the United States sits atop vast untapped spectrum resources that can be readily exploited to further the Commission's broadband goals and help bridge the digital divide.⁶⁵ Even those who disagree on the right mix of licensed and unlicensed spectrum allocations agree on one point: "Nearly any licensed or unlicensed use is preferable to leaving spectrum unused."⁶⁶ For the reasons discussed above, unlicensed applications should be part of any new spectrum allocations.

* * *

⁶⁴ See, e.g., *id.* at 51. See also Paramvir Bahl, Ranveer Chandra, Thomas Moscibroda, Rohan Murty, Matt Welsh, *White Spaces Networking with Wi-Fi like Connectivity*, Microsoft Research, at 2 (August 2009), available at <http://research.microsoft.com/pubs/80952/whitafi.pdf> (visited Sep. 14, 2009) (referencing ranges "expected to exceed 1 km).

⁶⁵ See, e.g., California PUC Comments at 23, Cisco Comments at 16, CCIA Comments at 22, CEA Comments at 6-9, CFA and CU Comments at 31, CTIA Comments at 26, Dell Comments at 11, Google Comments at 16-17, Intel Comments at 20-21, Motorola Comments at 6, New America Foundation Comments at 15-20, Public Knowledge Comments at 31-33, Southern Company Comments at 6-7, TIA Comments at 19, T-Mobile Comments at 16-18, Verizon Wireless Comments at 68-69 (all filed June 8, 2009).

⁶⁶ Coleman Bazelon, *Licensed or Unlicensed: The Economic Considerations in Incremental Spectrum Allocations*, IEEE Communications Magazine, March 2009, at 111; see also Michael Calabrese, *The End of Spectrum 'Scarcity': Building on the TV Bands Database to Access Unused Public Airwaves*, New America Foundation, Working Paper #25, June 2009, available at http://www.newamerica.net/files/Calabrese_WorkingPaper25_EndSpectrumScarcity.pdf (visited Aug. 6, 2009).

Microsoft welcomes the opportunity to provide additional thoughts on how to ensure that the United States becomes a global leader in broadband connectivity. Pursuant to section 1.1502 of the Commission's rules, a copy of this letter is being filed electronically in the above-referenced docket. If you require any additional information on the positions described herein, please contact the Paula Boyd at 202-263-5946 or pford@microsoft.com.

Sincerely,

/s/

Craig Mundie
Chief Research & Strategy Officer

/s/

Anoop Gupta
Corp. Vice President – Technology Policy & Strategy

Attachment